A SYNTHETIC STUDY OF

4-*t*-BUTYLCYCLOHEXYLMAGNESIUM CHLORIDE

A THESIS

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The Faculty of the Division of Graduate Studies

By

Gloria Mary Mischuk

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A SYNTHETIC STUDY OF

4-t-BUTYLCYCLOHEXYLMAGNESIUM CHLORIDE

Approved:

Erling Grovenstein, Jr.
Chairman

Drury Caine

Herbert House
Research Advisor

Date approved by Chairman Aug 28, 1978

to

my parents,

my brother,

ron,

and

hh

ACKNOWLEDGEMENTS

The author first of all would like to express her appreciation to her research advisor, Herb House, for providing her with this project and his guidance. She would also like to thank him for those summer therapy sessions, helping to write her thesis, and especially getting her on the ice both standing and sitting. The author also thanks Dr. E. Grovenstein for substituting for Dr. Stanfield as chairman and Dr. D. Caine for serving as the second reader. Thanks should also be extended to her co-workers in the lab for their encouragement and assistance in preparing this thesis. Special thanks are sent to Ron Sieloff for his assistance in typing and preparation of the schemes herein. Last but not least, the author would like to thank her parents for their support and encouragement throughout her acedemic career.

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SUMMARY

This research was concerned with a synthetic investigation of 4-t-butylcyclohexylmagnesium chloride. First, the starting chlorides cis- and trans-4-t-butylcyclohexyl chloride were prepared. Second, authentic samples of the hydrocarbons (t-butylcyclohexane, 4-t-butylcyclohexene, and the isomeric 4'-t'-butylcyclohexyl-4-t-butylcyclohexanes) that are also formed in the preparation of this Grignard reagent were obtained.

Nmr analysis was attempted to determine the stereoisomeric composition of this Grignard reagent, but without success. Therefore, carbonation was done and indicated a 3:1 preference of the equatorial acid. Another chemical method was tried. Deuterium oxide was added to the Grignard reagent. This time the ^{13}C nmr spectra of the deuterated hydrocarbons were not sufficiently resolved to separate the cis from the trans deuteriated hydrocarbon.

The study of additions of carbonyl compounds to this Grignard reagent was begun. Since the two carbonyl compounds in question are benzophenone and acetone the corresponding carbinols were prepared. The only addition looked at was that of acetone which yielded only the trans carbinol.

CHAPTER I

DISCUSSION

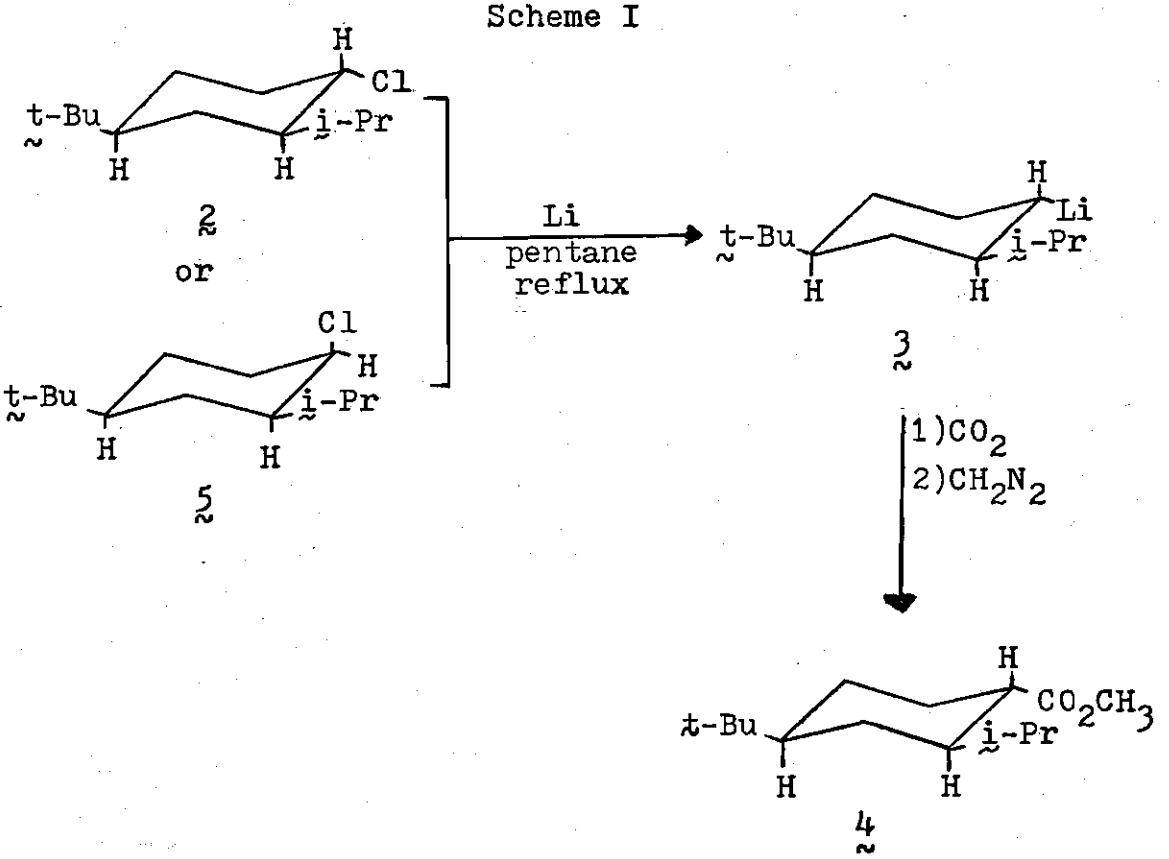
Introduction

The following investigation was concerned with the synthetic study of 4-t-butylcyclohexylmagnesium chloride (1). The first endeavor was an attempt to ascertain the stereoisomeric composition of this Grignard reagent. While the second part deals with the stereochemistry of reaction for this Grignard reagent 1 with such substrates as carbon dioxide, deuterium oxide, and acetone.

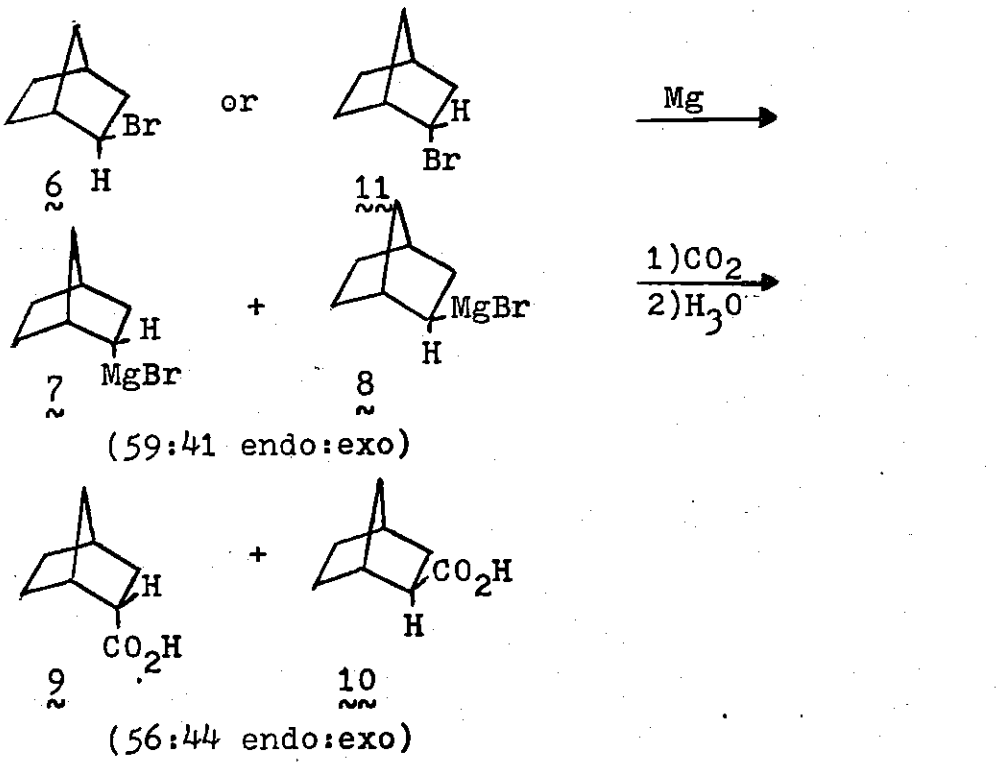
It has been verified[1,2,3,4] that carbonation can be used to establish the configuration of lithium and magnesium organometallics. In the case of menthyllithium (3) it has been reported[2,4] that configurational stability was indicated by nmr analysis and confirmed by the carbonated product 4 (see Scheme I). In the case of an organomagnesium reagent, Jensen and Nakamaye[3] have shown by nmr analysis that a 59:41 endo:exo ratio of isomeric norbornylmagnesium bromides 7 and 8 could be carbonated to yield a 56:44 endo:exo mixture of acids 9 and 10 (see Scheme II).

However, Glaze and co-workers[4] could not verify by nmr the carbonation results for their 4-t-butylcyclohexyllithium reagent (13) due to its insolubility in diethyl ether. They

Scheme I

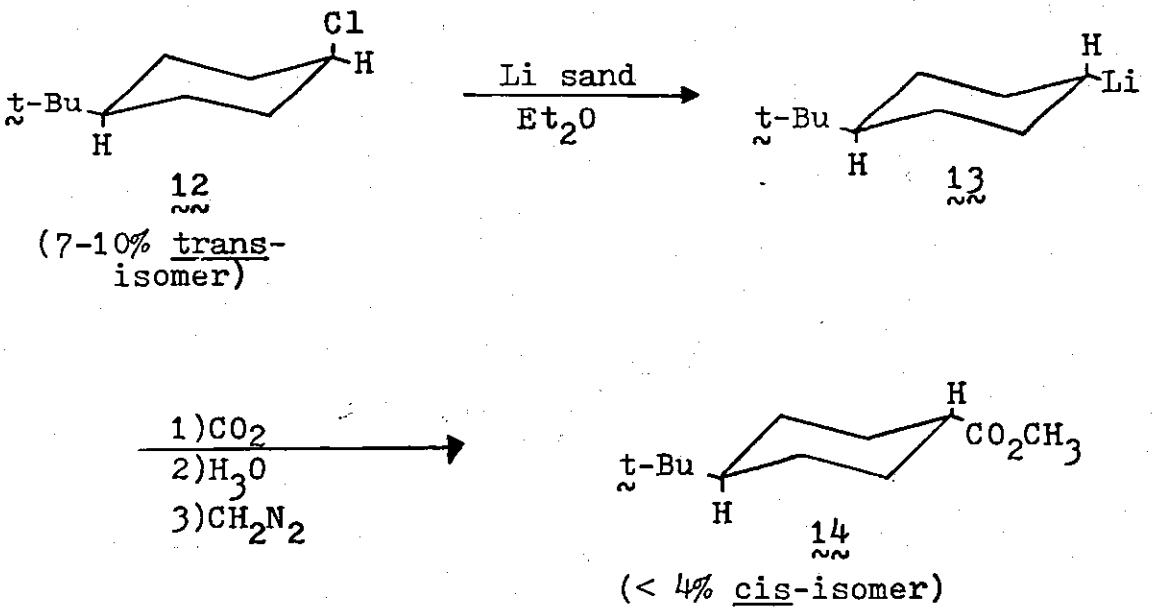


Scheme II



prepared[5] this reagent from cis-4-t-butylcyclohexyl chloride (12) (7-10% trans-isomer) and lithium sand. Upon carbonation and subsequent treatment with diazomethane, methyl-trans-4-t-butylcyclohexylcarbonate (14) was obtained (only 4% cis-isomer) (Scheme III).

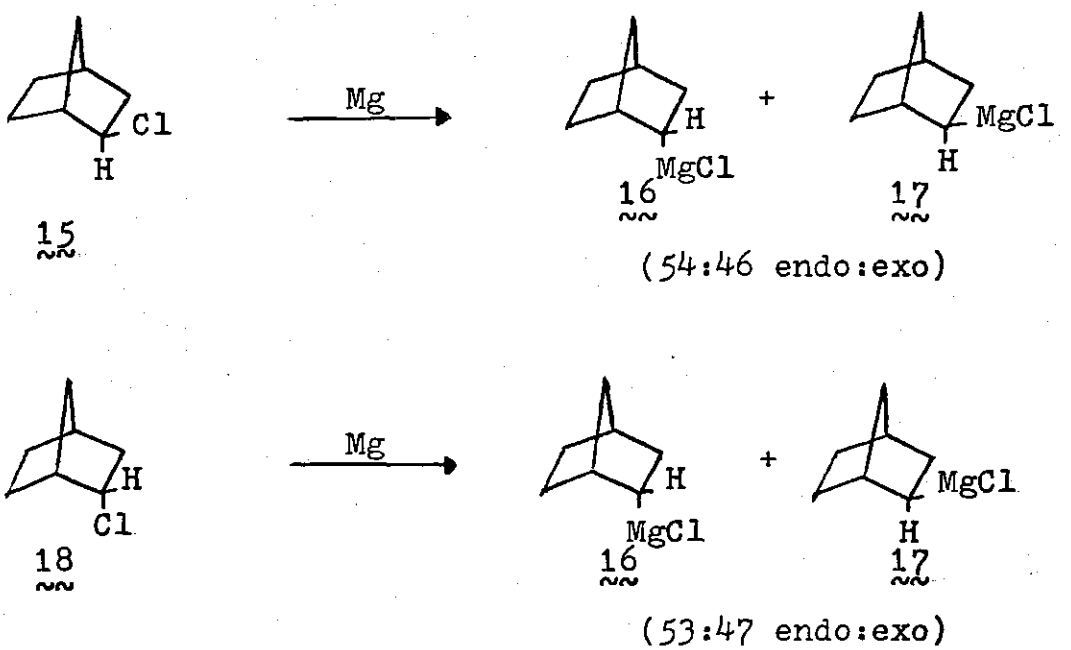
Scheme III



This brings us to a very important point about the formation of secondary organo-lithium and magnesium reagents. As indicated above in the preparation of menthyllithium (3) and 4-t-butylcyclohexyl lithium (13), the stereochemistry of the starting halide and the organolithium are not the same. In the case of organomagnesium compounds, we also see a loss of stereochemistry from the starting halide. For example in

the norbornyl system Jensen and Nakamaye[3] showed that with either the pure endo or exo bromide 6 or 11 a 59:41 ratio of endo:exo Grignard reagents 7 and 8 was formed (Scheme II). Also, Krieghoff and Cowan[5] found that with pure endo chloride 15 and pure exo chloride 18 a 54:46 and 53:47 ratio of endo:exo Grignard reagents 16 and 17 were obtained, respectively (Scheme IV).

Scheme IV



15 → 16 + 17 (54:46 endo:exo)

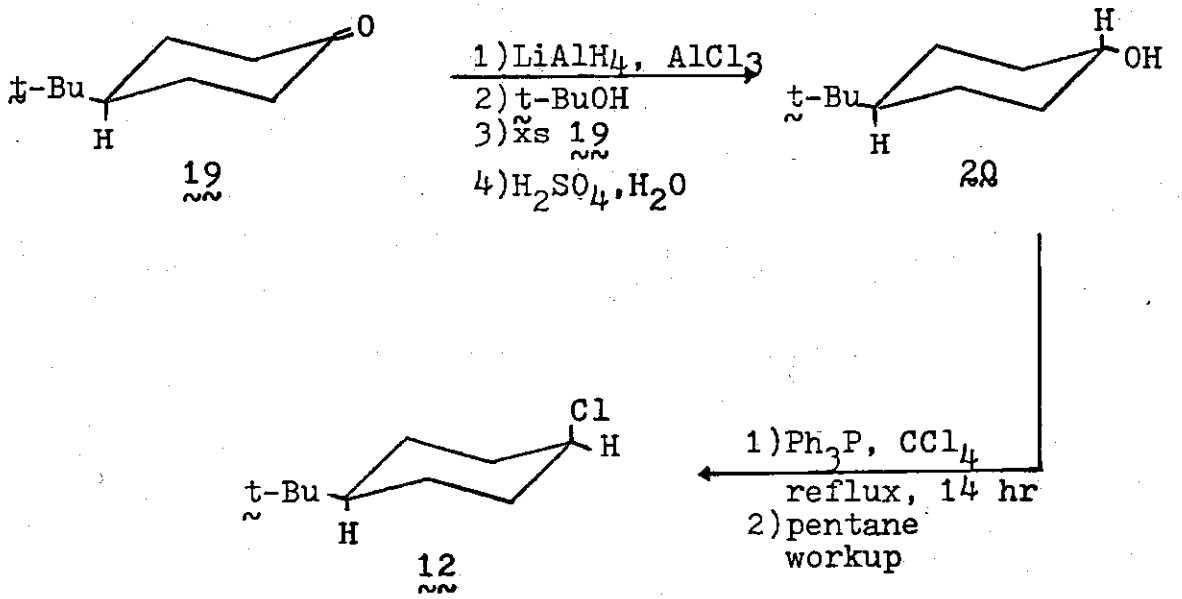
18 → 16 + 17 (53:47 endo:exo)

Discussion of Results

Before looking at 4-t-butylcyclohexylmagnesium chloride (1) the starting cis-4-t-butylcyclohexyl chloride (12) and

trans-4-t-butylcyclohexyl chloride (23) had to be prepared. One synthesis for the cis chloride 12 involved the isolation of trans-4-t-butylcyclohexanol (20) prior to formation of the chloride 12 as shown in Scheme V. A much simplier pro-

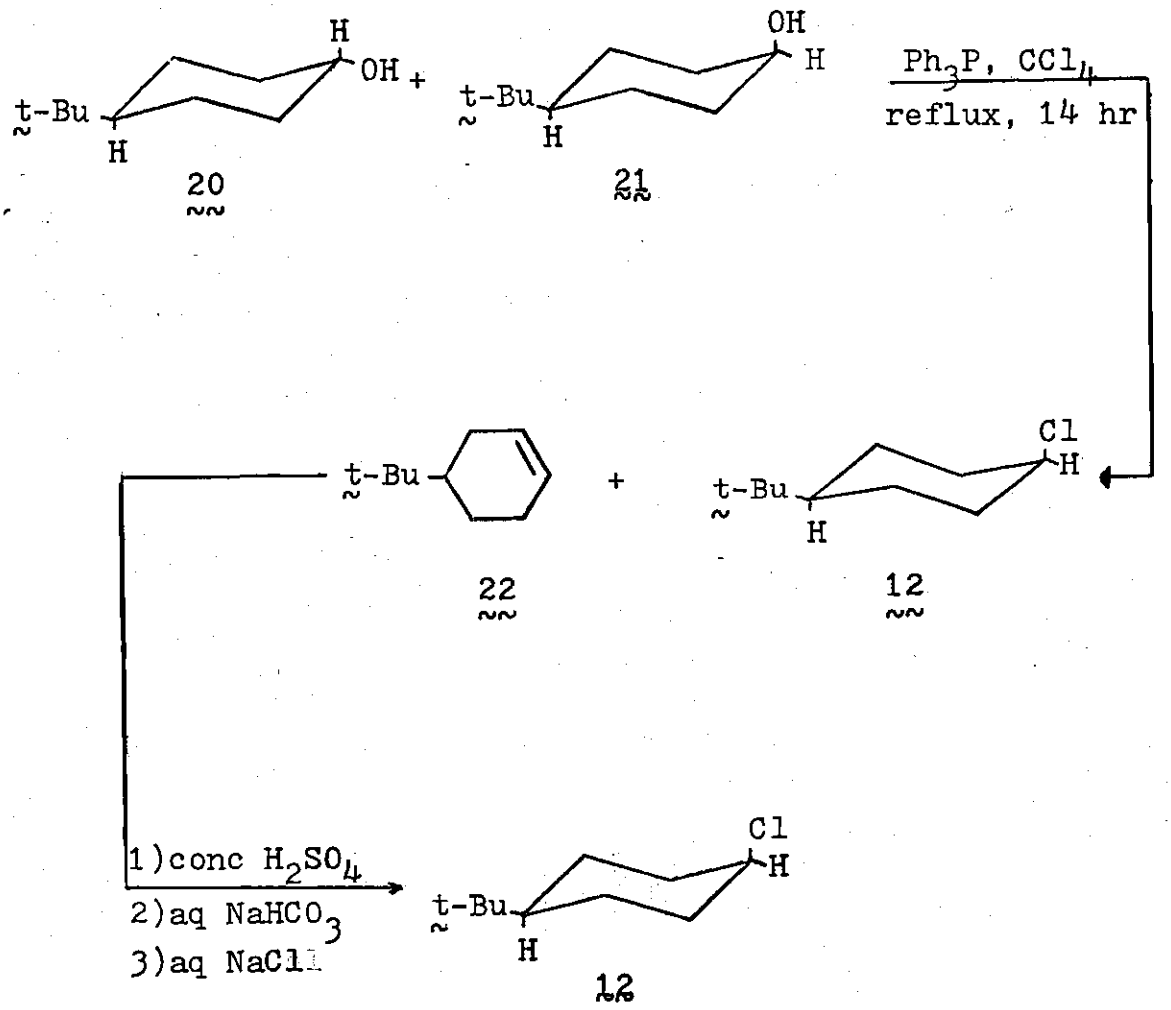
Scheme V



cedure was used later in which a commercial mixture of stereoisomeric 4-t-butylcyclohexanols 20 and 21 was treated with triphenylphosphine and carbon tetrachloride. Subsequently the reaction mixture was washed with concentrated sulfuric acid to remove the by-product, 4-t-butylcyclohexene (22) (Scheme VI).

In order to prepare trans-4-t-butylcyclohexyl chloride (23) a commercial mixture of steroisomeric 4-t-butylcyclohexanols 20 and 21 was first converted into a mixture of iso-

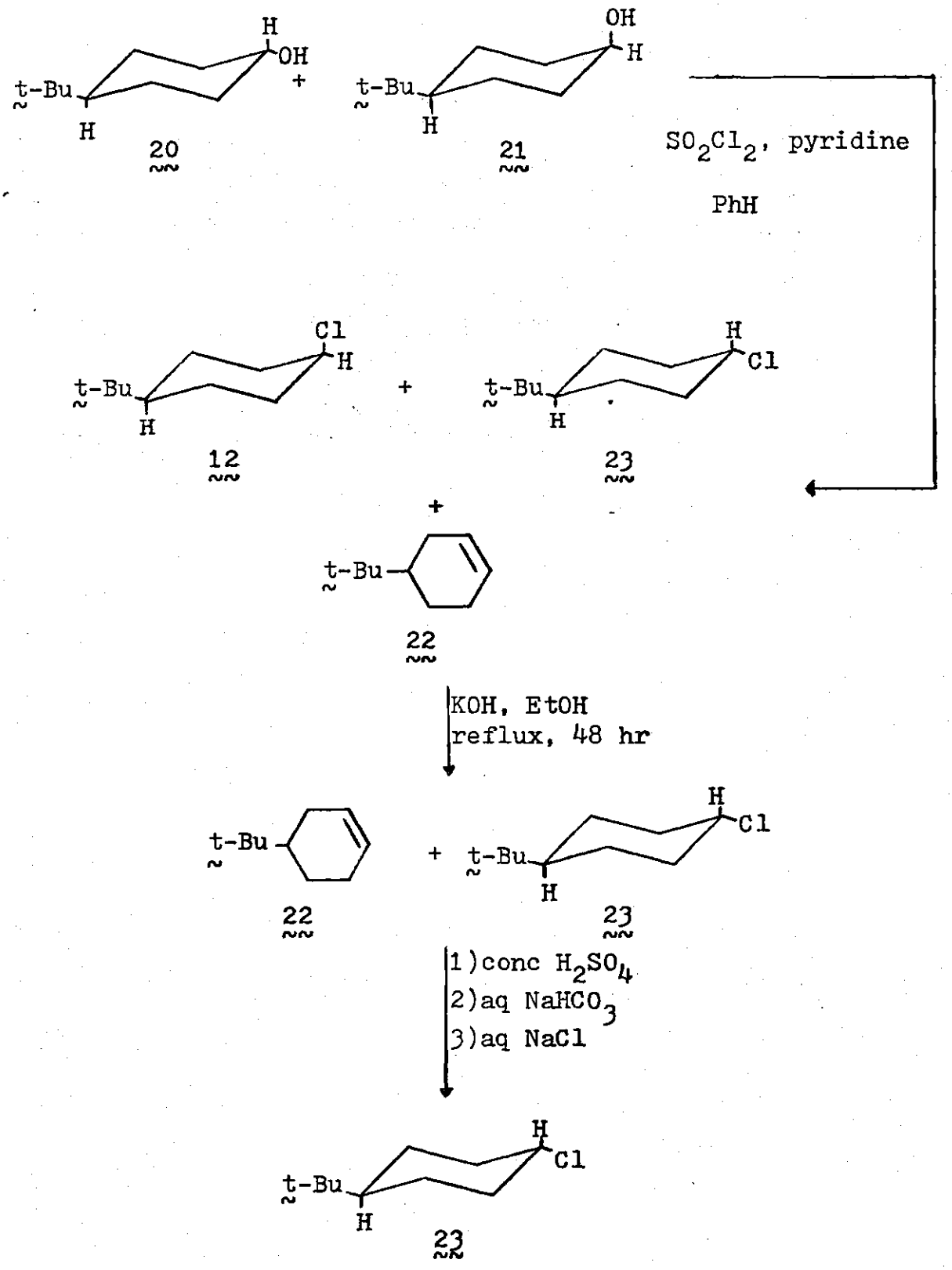
Scheme VI



meric chlorides 12 and 23 along with the corresponding olefin 22. This mixture was then treated with base to dehydrohalogenate selectively the axial chloride 12.[8] The olefin 22 was then removed by washing the mixture with concentrated sulfuric acid (Scheme VII).

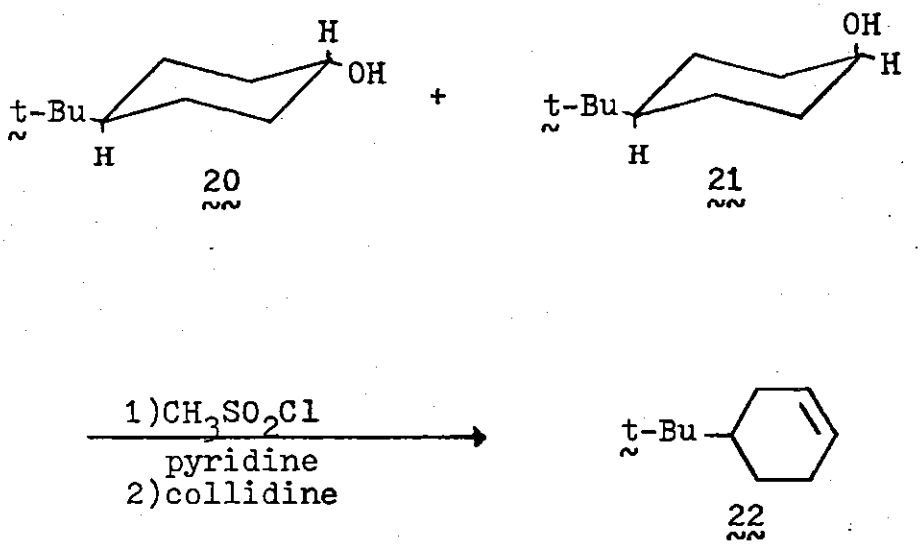
Authentic samples of the hydrocarbons formed in the preparation of 4-t-butylcyclohexylmagnesium chloride (1) were

Scheme VII

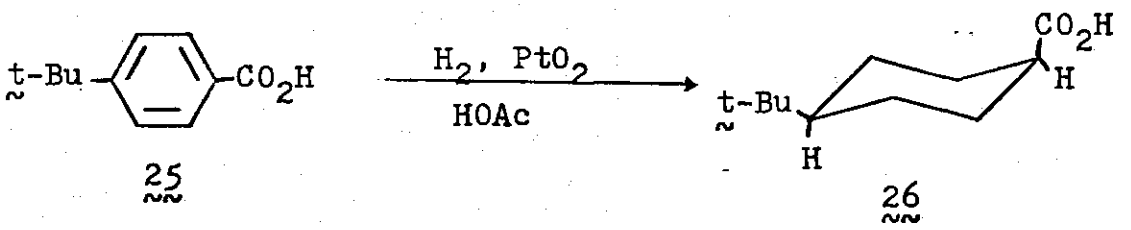

t-Bu
H
OH
20
21
SO_2Cl_2, pyridine
PhH
Cl
12
23
22
KOH, EtOH
reflux, 48 hr
1)conc H_2SO_4
2)aq $NaHCO_3$
3)aq NaCl

obtained. t-Butylcyclohexane (24) was purchased from Aldrich Chemical Company, Inc. 4-t-Butylcyclohexene (22) was prepared as shown in Scheme VIII and the isomers of 4'-t'-butylcyclohexyl-4-t-butylcyclohexane 27, 28, and 29 were made as shown in Scheme IX.

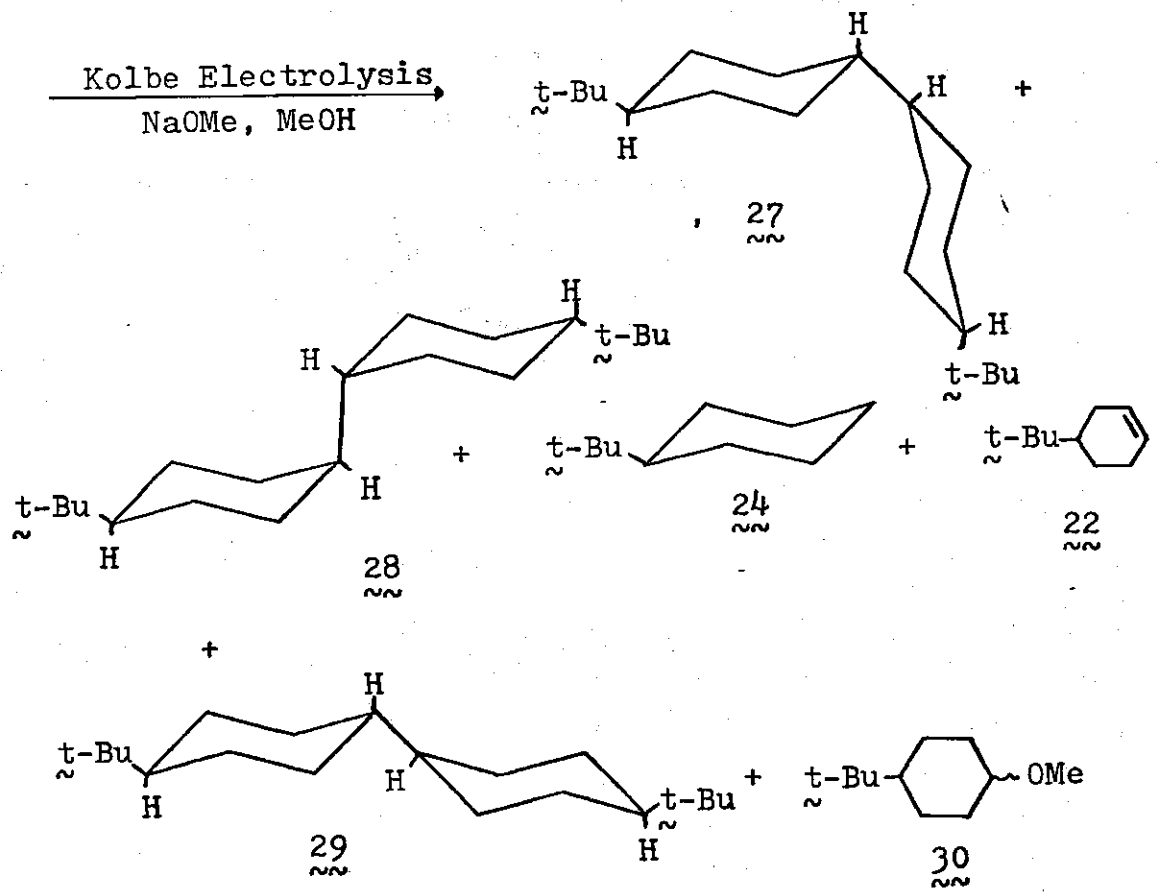
Scheme VIII



Scheme IX



Scheme IX
(cont.)



The isomeric 4'-t'-butylcyclohexyl-4-t-butylcyclohexanes 27, 28, and 29 were separated on gplc with a 13.5 ft. silicone QF_1 column. The major isomer of the Kolbe reaction was 27 whose stereochemistry was assigned by ^1H nmr analysis. The two t-butyl peaks were observed at δ 0.84 and 0.83. The other two isomers 28 and 29 were also analyzed by ^1H nmr and exhibited only one t-butyl peak each at δ 0.83 and 0.81,

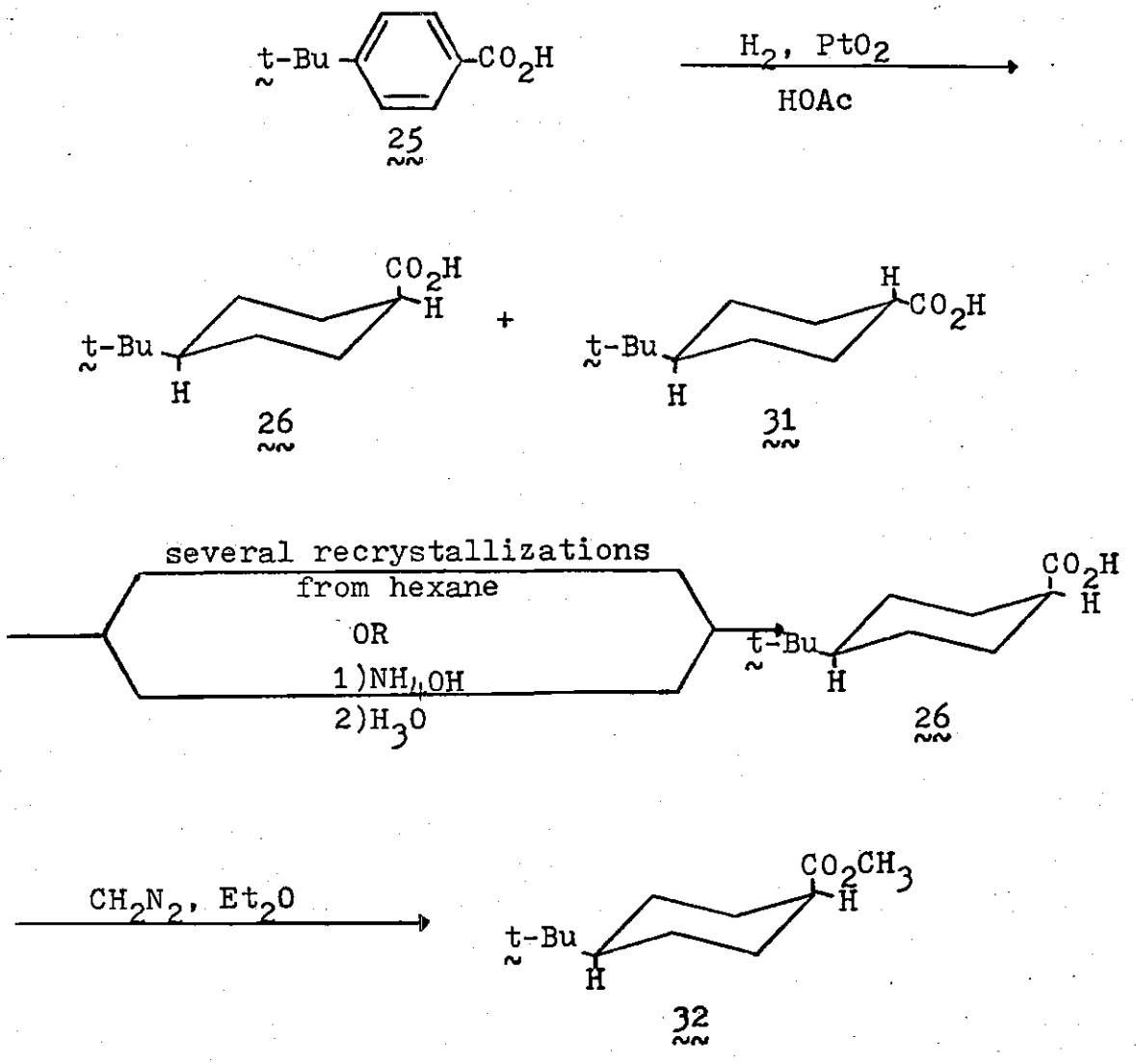
respectively. Utley and co-workers[9] distinguished between isomers 27 and 29 by hydrogenating trans-1-t-butyl-4-(4-t-butylcyclohexyl)benzene which yielded 27 and 29. Because the starting material contains a trans-linkage (equatorial) it follows that the two dimers formed are the a,e and e,e isomers. The a,a isomer must therefore be the other isomer. Their gplc work was done with a 2.5% SE_{30} column. We correlated the retention times of these isomers, 27, 28 and 29, on a 2.5% SE_{30} column with the retention times of these materials on a silicone QF_1 column.

The Grignard reagent 1 was initially prepared from cis-4-t-butylcyclohexyl chloride (12) in diethyl ether. Due to the spinning side bands for the methyl nmr signal of diethyl ether it was impossible to determine the stereoisomeric composition of 1 in this solvent. An alternative solvent, THF, was tried; however, in this case both signals for the hydrogens on the carbon bearing the magnesium coincided.

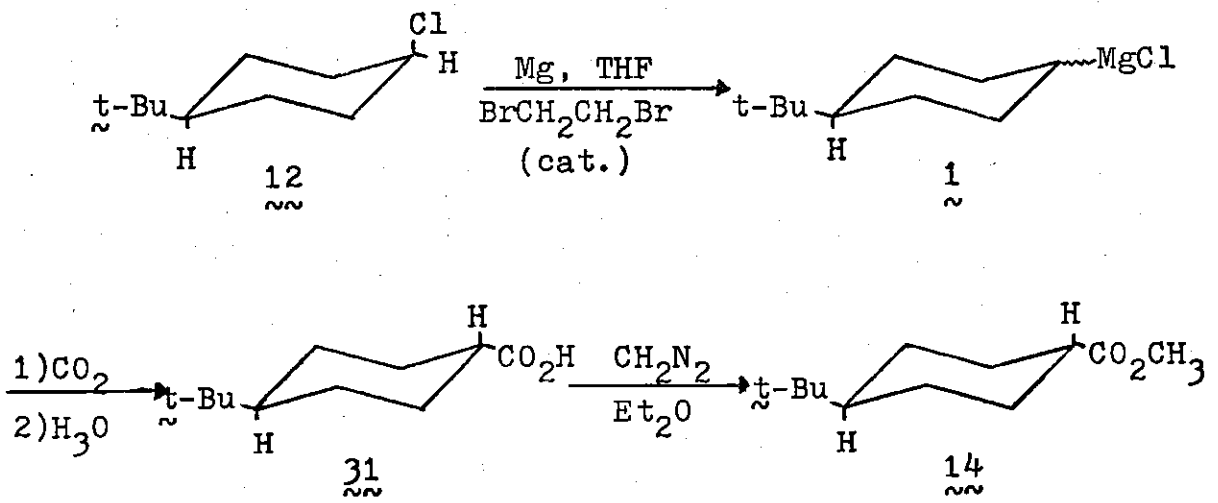
Consequently, alternative chemical methods were sought to determine the stereoisomeric composition of 4-t-butylcyclohexylmagnesium chloride (1). As discussed above, carbonation had been used to verify ^1H nmr results on lithium and magnesium organometallics. Therefore, this chemical method was tried first. The method of analysis was glpc of cis-methyl 4-t-butylcyclohexanoate (32) and trans-methyl-4-t-butylcyclohexanoate (14), the esters, resulting from esterifying the carbonation product of this Grignard reagent 1. The prepara-

tions of the two esters 32 and 14 are shown in Schemes X and XI.

Scheme X

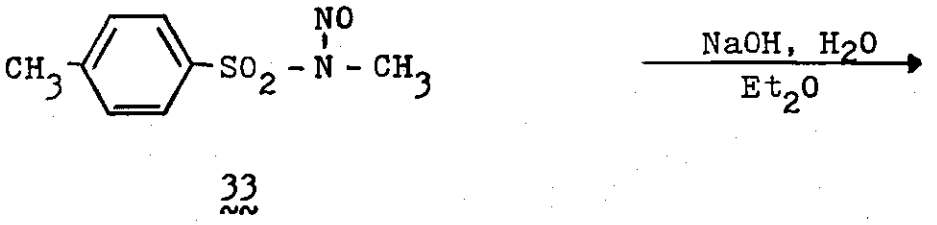


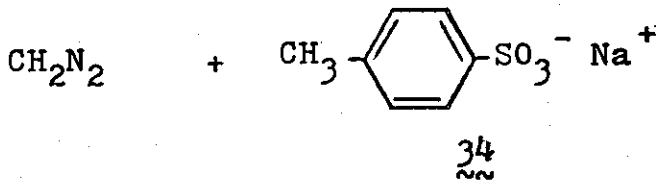
Scheme XI



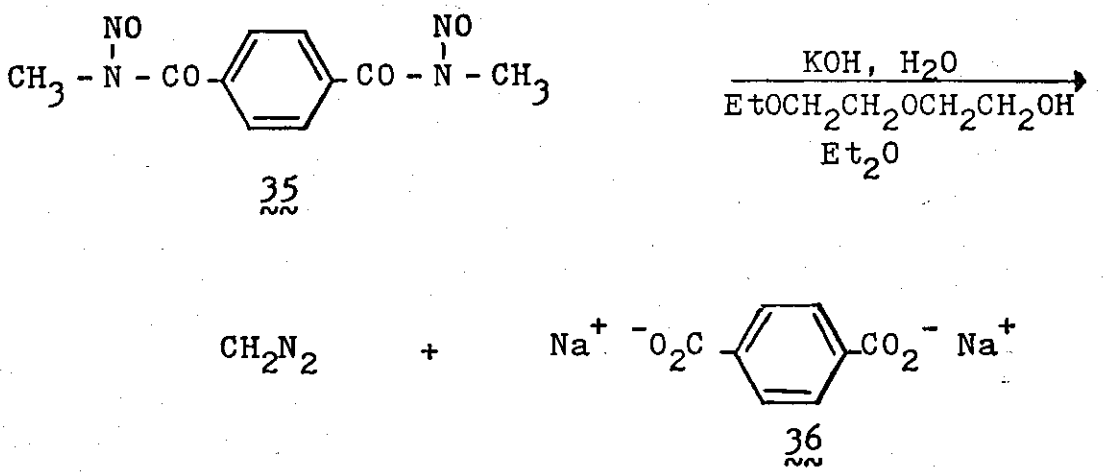
Ethereal solutions of diazomethane were prepared from either N,N'-dimethyl-N,N'-dinitrosoterephthalamide (33)[10] or nitroso-methylurethane (35),[11] as shown in Schemes XII and XIII.

Scheme XII





Scheme XIII



35 36

4-t-Butylcyclohexylmagnesium chloride (1) was prepared separately from both cis-4-t-butylcyclohexyl chloride (12) and trans-4-t-butylcyclohexyl chloride (23), carbonated, and esterified with ethereal solutions of diazomethane. Both sets of reactions yielded identical ratios of cis-methyl-4-t-butylcyclohexanoate (32) and trans-methyl-4-t-butylcyclohexanoate (14) (1:3) (see Table 1). These results are in disagree-

TABLE 1[a]

Percent yields of carbonation of 4-t-butylcyclohexyl magnesium chloride (1) experiments.

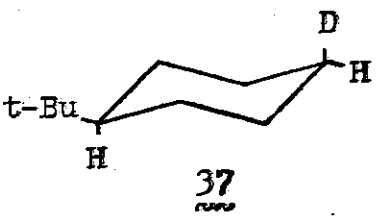
chloride	%1	%26+31	%24	%22	%27	%28	%29	%32	%14
12(cis)	89	83	13	3	2	0.3	1	21	61
23(trans)	83	76	17	2	3	0.5	0.5	18	53

[a]based on moles of starting chloride

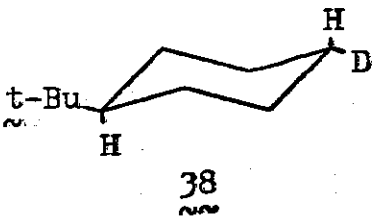
ment with Jensen and Nakamaye[12] who claimed to obtain only trans-4-t-butylcyclohexanoic acid (31) upon carbonation of the 4-t-butylcyclohexyl Grignard reagent.

Another chemical procedure that was tried, in order to obtain a stereoisomeric composition of 4-t-butylcyclohexylmagnesium chloride (1) was to quench the Grignard reagent 1 with deuterium oxide. At the present time an accurate method to determine the amount of deuterium incorporation is not available. Based on the results of Doddrell, Kitchinck, Adcock, and Wiseman[13] we felt that ^{13}C nmr had a possibility of being feasible to distinguish cis-4-t-butyldeuteriocyclohexane (37) and trans-4-t-butyldeuteriocyclohexane (38) (see Scheme XIV). However, the resolution obtained was not sufficient. A more feasible instrumental technique may be ^{2}H nmr since the deuteriums appear at +5.98 and +5.42 ppm relative to $CDCl_3$ for 37 and 38, respectively.[14]

Scheme XIV



37



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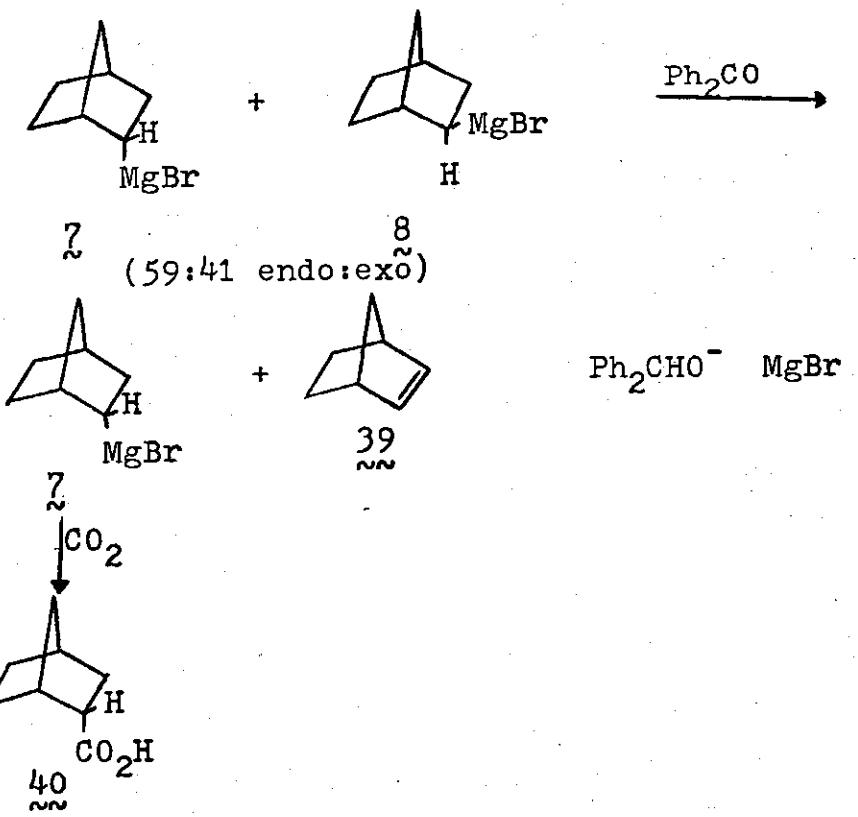
Not until recently has a detailed understanding of the addition of carbonyl compounds to Grignard reagents begun to

emerge.[15] Jensen and Nakamaye[3] have allowed an equilibrium mixture of norbornylmagnesium bromides 7 and 8 to react with less than a stoichiometric amount of benzophenone and observed that the exo-norbornylmagnesium bromide (8) eliminated to the corresponding olefin 39, and the endo-norbornylmagnesium bromide (7) was left intact (see Scheme XV).

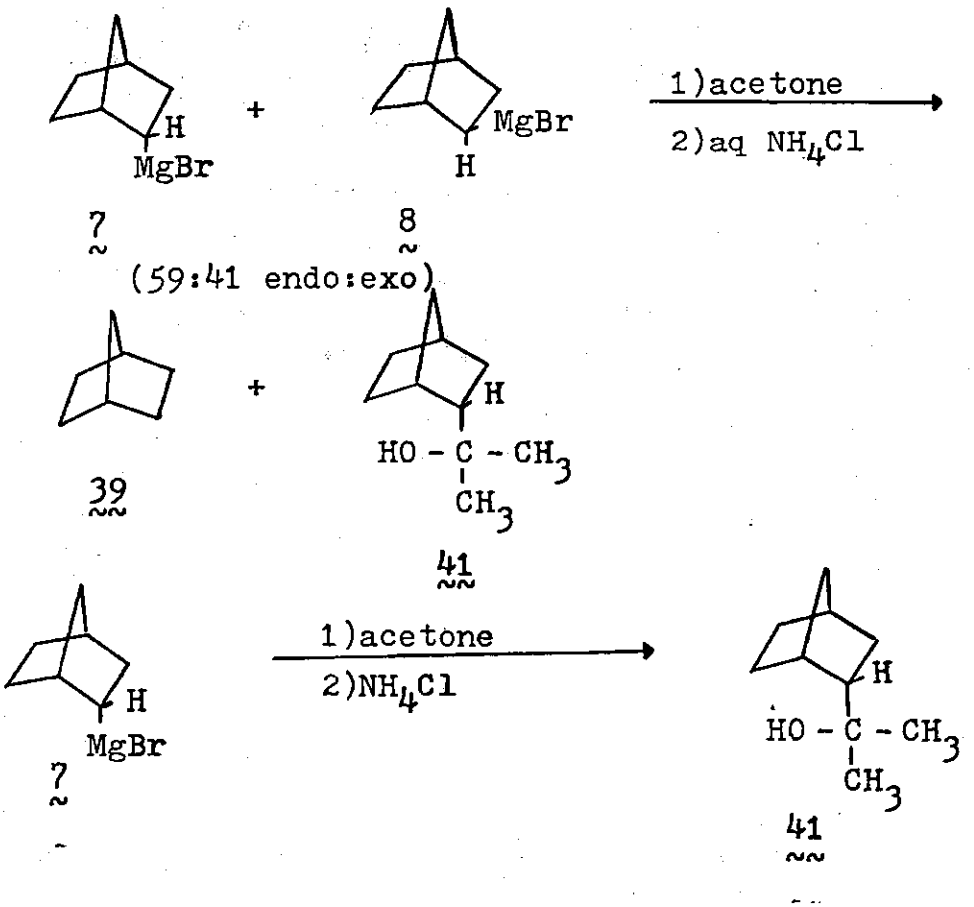
Scheme XV



Similarly San Filippo and Nicoletti[15] have allowed norbornylmagnesium bromides 7 and 8 to react with acetone and observed the formation of olefin 39 and endo-carbinol 41. To prove that olefin 39 was generated from exo-norbornylmagnesium

bromide (8); and that endo-norbornylmagnesium bromide (7) yields the carbinol 41, they allowed pure endo-norbornylmagnesium bromide (7) to react with acetone. In this reaction they only observed the endo-carbinol 41 with no olefin 39 being detected (see Scheme XVI).

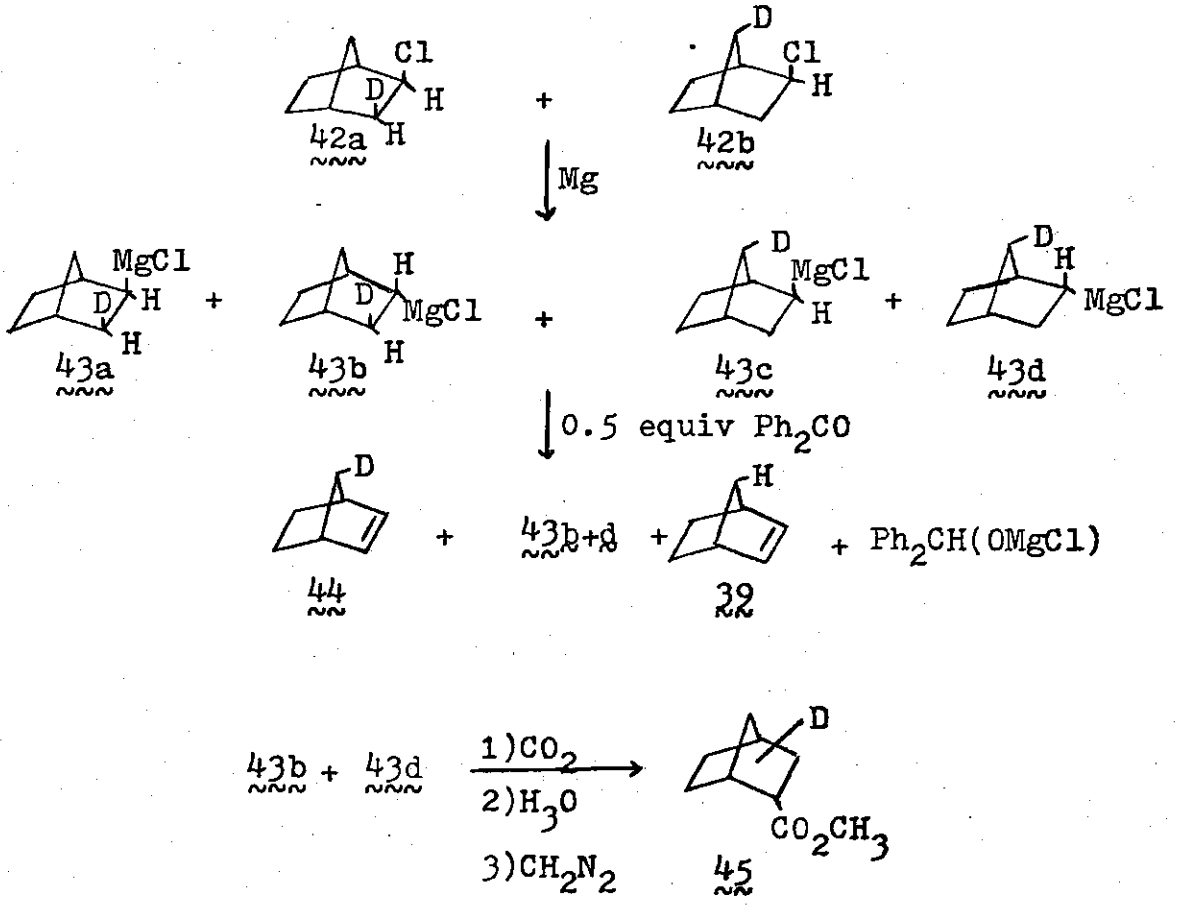
Scheme XVI



The destruction of exo-norbornylmagnesium bromide (8) with either benzophenone or acetone, via an elimination process rather than an additive process, is consistant with the geometry of the norbornyl system and the cis-exo type of elimination

reactions these systems undergo. Morrison and Lambert[16] have shown that the cis-exo elimination process is present in the reaction of benzophenone with the Grignard reagent 43 from the equilibrium (55:45) mixture of 2-exo-chloro-3-exo-deuterionorbornane (42a) and 2-exo-chloro-7-syn-deuterionorbornane (42b) (Scheme XVII).

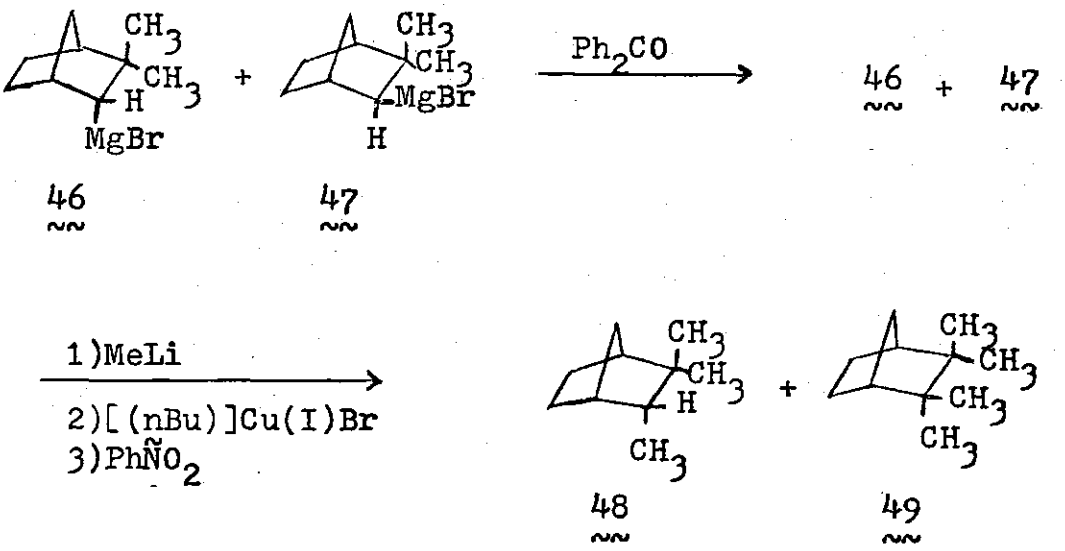
Scheme XVII



San Filippo and Nicoletti[15] have also examined a bicyclic system where a β-elimination process is impossible. When an

equilibrium mixture of 3,3-dimethyl-2-norbornylmagnesium bromides 46 (endo) and 47 (exo) was allowed to react with increasing amounts of benzophenone, there was a decrease in the endo:exo ratio. This ratio was determined by the analysis of the methylated products 48 and 49 formed from the Grignard reagents 46 and 47 (see Scheme XVIII). When no

Scheme XVIII



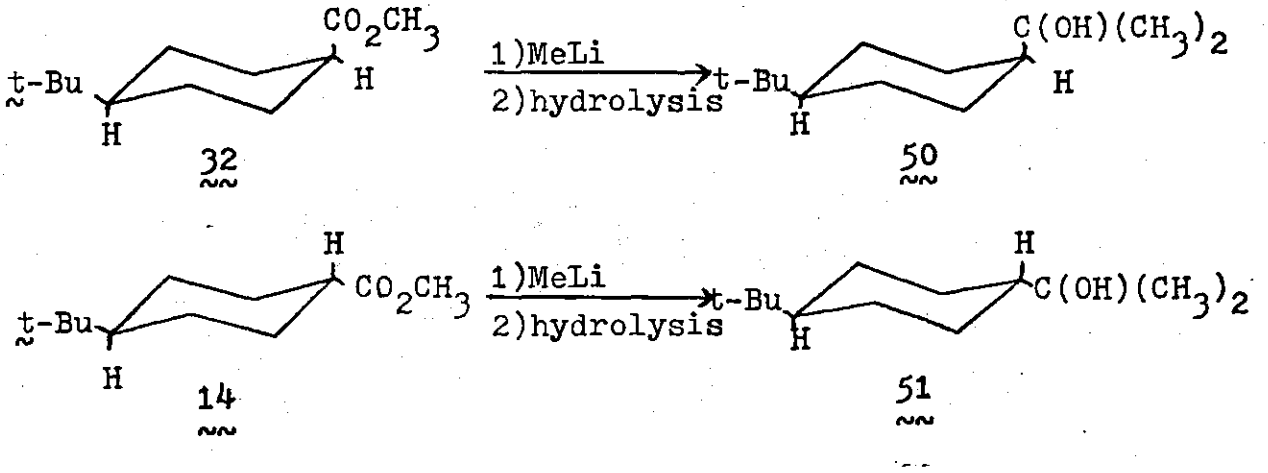
benzophenone was added a 84:16 ratio of 48 to 49 was observed. When 0.8 equivalent benzophenone was added a 44:56 ratio of 48 to 49 resulted. From these results San Filippo and Nicoletti have suggested that electron transfer may also play a role and that an elimination reaction in the reaction of norbornylmagnesium bromides 7 and 8 with benzophenone or with acetone

may not be a β-hydrogen elimination process.

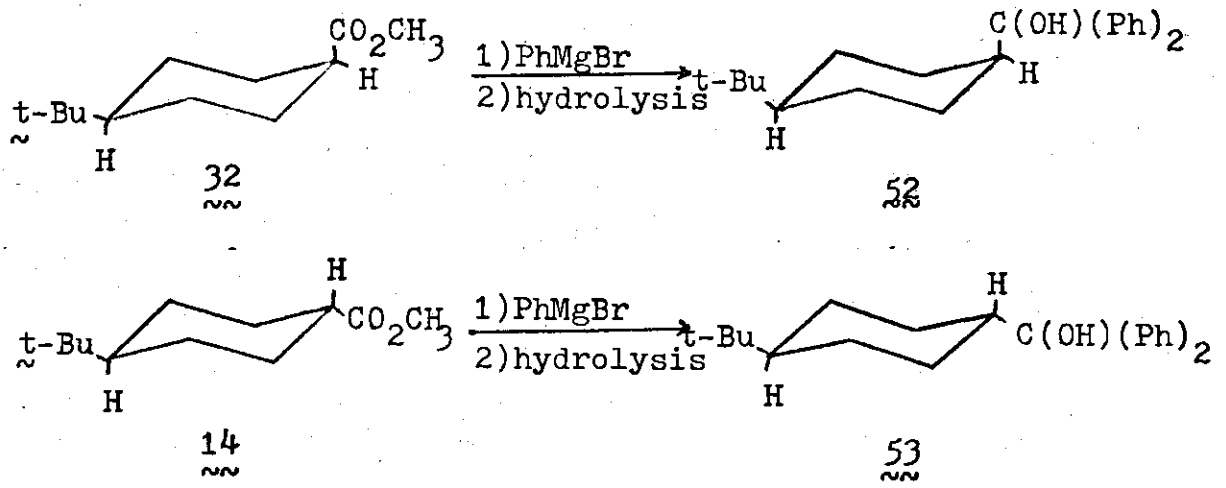
By looking at our model, 4-t-butylcyclohexylmagnesium chloride (1), we hope to gain more insight about the reaction of carbonyl compounds with Grignard reagents. Can benzophenone selectively destroy one of the stereoisomer and leave the other one intact? Will acetone cause an elimination reaction with one of the stereoisomers of our Grignard reagent 1 and also yield only one carbinol?

So far authentic sample of the four possible carbinols 50, 51, 52, and 53 that could result when 4-t-butycyclohexylmagnesium chloride (1) adds to either acetone or benzophenone have been prepared. The preparations of these carbinols are shown in Schemes XIX and XX.

Scheme XIX



Scheme XX



When acetone was added to a cold solution of Grignard reagent 1 only the carbinol 51 was obtained.

This however is where the work stopped. It is my opinion that much work still remains to be undertaken along these lines. Possible endeavors that I feel would be of great help and interest are enumerated below.

1) Deuterium nmr should be examined to determine the stereoisomeric composition of 37 and 38.

2) The reaction of adding benzophenone to the Grignard reagent 1 needs to be done. An ESR spectrum of the reaction mixture should be able to show if an electron-transfer reaction is going on. Also the yields of products after hydrolysis need to be measured and compared with the yields obtained from the carbonation experiments.

3) Carbonation, after the addition of benzophenone to

Grignard reagent $\underset{\sim}{1}$ should be done in order to determine it only the equatorial acid is formed. An also the addition of acetone to the reaction mixture of benzophenone and the Grignard reagent $\underset{\sim}{1}$ needs to be done and see if a comparable amount of <u>trans</u> carbinol $\underset{\sim\sim}{51}$ forms.

CHAPTER II

EXPERIMENTAL[17]

Preparation of trans-4-t-butylcyclohexanol (20)

The reduction of 77.8 g (500 mmol) of 4-t-butylcyclohexanone (19) with $LiAlH_4$ and $AlCl_3$ in Et_2O solution as previously described[7] yielded 71.4 g (91.4%) of trans-4-t-butyl cyclohexanol (20) as colorless needles, mp 76-79° (lit.[7] mp 75-78°); ir (CCl_4), 3610 and 3350 (broad) cm^{-1} (OH); nmr (CCl_4), δ 3.2-3.6 (1 H, m, OCH) and 0.8-2.1 (19 H, m, aliphatic CH and OH including a t-Bu singlet at 0.83). Mixtures of trans-4-t-butylcyclohexanol (20) and cis-4-t-butylcyclohexanol (21) were available commercially either from Aldrich Chemical Company, Inc. or from Columbia Organic Chemicals Co., Inc. These mixtures contained (glpc, Carbowax 20M on Chromosorb P) ca. 25% of the cis alcohol 21 (ret. time 21.4 min) and ca. 75% of the trans alcohol 20 (25.4 min). A collected (glpc) sample of the cis alcohol 21 had the following spectral properties: ir (CCl_4), 3615, 3480, and 3360 cm^{-1} (OH); nmr (CCl_4), δ 3.9-4.1 (1 H, m, OCH), and 0.8-2.0 (19 H, m, aliphatic CH and OH including a t-Bu singlet at 0.83). Mixtures of the alcohols 20 and 21 could also be analyzed by measuring the relative areas under multiplets at 3.9-4.0 (cis

alcohol 21 and 3.2-3.6 (trans alcohol 20).

Preparation of cis-4-t-butylcyclohexyl chloride (12)

A solution of 30.11 g (193 mmol) of a commercial mixture of trans-4-t-butylcyclohexanol (20) and cis-4-t-butylcyclohexanol (21) (ca. 75% of 20 and 25% of 21) and 60.41 g (230 mmol) of Ph_3P (freshly recrystallized, dried in a vacuumed desiccator for 24 hr with P_2O_5, mp 80-81°) in 500 ml of CCl_4 (distilled from P_2O_5) was refluxed for 22 hr and then cooled and diluted with 400 ml of pentane to precipitate most of the Ph_3PO. The mixture was filtered and the pentane solution was washed successively with concentrated H_2SO_4, with H_2O, with aqueous $NaHCO_3$, and with aqueous NaCl. The organic layer was then dried and distilled. Since the distillate still contained (nmr analysis) some 4-t-butylcyclohexene (22), it was diluted with 30 ml of pentane and again washed successively with concentrated H_2SO_4 (three 20 ml portions) and then H_2O, aqueous $NaHCO_3$, and aqueous NaCl. The solution was dried and distilled to separate 23.27 g (69%) of the pure (nmr and glpc analysis) cis chloride 12, bp 65-68° (0.8 mm), $n^{25}D$ 1.4667 (lit.[18] bp 125.0° (49 mm), $n^{20}D$ 1.4694); nmr (CCl_4), δ 4.38 (1 H, m, CHCl) and 0.8-2.3 (18 H, m, aliphatic CH including a t-Bu singlet at 0.85); mass spectrum, m/e (rel. intensity), 139 (1), 138 (5), 81 (20), 67 (22), 57 (100),

56 (26), 43 (65), and 41 (30).

When the same procedure was repeated with 3.12 g (20 mmol) of pure trans-4-t-butylcyclohexanol (20), 6.82 g (26 mmol) of Ph_3P, and 50 ml of CCl_4, the yield of the cis chloride 12, bp 54-55° (1.5 mm), $n^{25}D$ 1.4670, was 3.22 g (92%).

Preparation of trans-4-t-butylcyclohexyl chloride (23)

A modification of a previously described[8] procedure was used to obtain trans-4-t-butylcyclohexyl chloride (23). To a cold (0-5°) solution of 33.0 g (211 mmol) of a commercial mixture of trans-4-t-butylcyclohexanol (20) and cis-4-t-butylcyclohexanol (21) and 1.47 g (18.6 mmol) of pyridine in 650 ml of PhH (distilled from $LiAlH_4$) was added, dropwise and with stirring during 20 min, 56.99 (479 mmol) of $SOCl_2$ (distilled from quinoline). After the addition was complete, the solution was warmed until gas evolution ceased (2.5 hr) and then refluxed for 40 hr. After the mixture had been cooled and poured onto ice, the PhH layer was separated and washed with 100 ml of concentrated aqueous H_2SO_4 (to remove unchanged alcohols and olefin). After the resulting PhH layer had been washed successively with H_2O, aqueous $NaHCO_3$, and aqueous NaCl, it was dried, concentrated, and distilled to separate 2.85 g of forerun, bp 50-60° (2.4 mm), containing (nmr analysis) 81% of 4-t-butylcyclohexene (22), and 19% of cis-4-t-

butylcyclohexyl chloride (12) followed by 18.30 g of fractions, bp 60-76° (2.4 mm), containing (nmr analysis) 11-48% of the olefin 22, 39-70% of the cis chloride 12, and 13-20% of the trans chloride 23. Although the mixture of chlorides was resolved on glpc (silicone QF_1 on Chromosorb P), the chromatogram exhibited not only peaks corresponding to the cis chloride 12 (ret. time 15.4 min) and the trans chloride 23 (18.2 min) but also peaks corresponding to the olefin 22 (3.4 min) and an unidentified component (4.1 min) thought to be an isomeric olefin. The olefinic components appeared to be formed during the glpc analysis. An 18.35 g sample of this mixture of olefin 22 and chlorides 12 and 23 was treated with a solution of 14.95 g (226 mmol) of KOH in 100 ml of EtOH and the resulting mixture was refluxed for 15 hr. After the reaction mixture had been partitioned between pentane and H_2O, the organic layer was washed repeatedly with small portions of concentrated aqueous H_2SO_4 (until all the olefin was removed), and then washed successively with H_2O, with aqueous $NaHCO_3$, and with aqueous NaCl. The organic layer was dried, concentrated, and distilled to separate 2.421 g (6.6% based on the alcohols 20 and 21) of the pure chloride 23 as a colorless liquid, bp 50-60° (1.8 mm), n^{25} D 1.4640 (lit.[19] n^{20} D 1.4656); nmr (CCl_4), δ 3.72 (1 H, m, CHCl) and 0.8-2.4 (18 H, m, aliphatic CH including a t-Bu singlet at 0.84); mass spectrum, m/e (rel. intensity), 123 (10), 81 (16), 67 (13), 57 (100), 56 (80), 55 (17),

43 (12), 41 (39), and 39 (10).

Properties of 4-t-butylcyclohexene (22) and t-butylcyclohexane (24)

To a cold (-40°) solution of 14.5 g (93 mmol) of a mixture of a commercial mixture of trans-4-t-butylcyclohexanol (20) and cis-4-t-butylcyclohexanol (21) in 60 ml of pyridine (distilled from CaH_2, bp 114°) was added, dropwise and with stirring, 19.8 g (158 mmol) of $MeSO_2Cl$. The resulting mixture was allowed to warm to 25° with stirring during 2 hr and then allowed to stand overnight. After the resulting solution had been cooled in an ice bath, 15 ml of H_2O was added and the resulting mixture was poured into 300 ml of H_2O. The crude brown solid mesylate was filtered, washed with H_2O, and allowed to dry. A solution of this crude mesylate in 60 ml of collidine [distilled from KOH, bp 58-58.5° (12 mm)] was refluxed for 3 hr and then cooled, poured into a mixture of ice and aqueous HCl, and extracted with pentane. After the pentane extract had been dried and concentrated, distillation separated 9.82 g (76.4%) of 4-t-butylcyclohexene (22) as a colorless liquid, bp 54-55° (12 mm), $n^{25}D$ 1.4572 (lit. $n^{20}D$ 1.4587,[19] 1.4583[20]); ir (CCl_4), 1655 cm^{-1} (C=C); nmr (CCl_4), δ 5.5-5.7 (2 H, m, vinyl CH) and 0.8-2.4 (16 H, m, aliphatic CH including a t-Bu

singlet at 0.85); mass spectrum, m/e (rel. intensity), 138 (M^+, 10), 82 (26), 81 (24), 80(24), 69 (27), 67 (35), 57 (100), and 41 (32).

A commercial sample (Aldrich Chemical Company, Inc.), of t-butylcyclohexane (24) exhibited the following spectral properties: ^{1}H nmr (CCl_4), δ 0.8-2.0 (m, aliphatic CH including a t-Bu singlet at 0.82); ^{13}C nmr ($CDCl_3$), 48.3, 32.6, 27.6 (2 C atoms), 27.4 (4 C atoms), 27.2 (2 C atoms), and 26.8 ppm.

GLPC response factors were determined (Carbowax 20M on Chromosorb P) for mixtures of 4-t-butylcyclohexene (22) and t-butylcyclohexane (24) with two different internal standards. With durene as a standard the retention times were: 24, 7.6 min; 22, 10.9 min; and durene, 45.2 min. With sec-butylbenzene as the standard the retention times were: 24, 7.2 min; 22, 10.6 min; sec-BuPh, 19.6 min.

Preparation of cis-4-t-butylcyclohexanoic acid (26)

A commercial sample of 4-t-butylbenzoic acid (25) was recrystallized from EtOH to separate the pure aromatic acid 25, mp 169-169.5° (lit.[21] mp 166-167°); nmr (CCl_4), δ 12.1 (1 H, s, OH), 8.0 (2H, d, J=9 Hz, aryl CH), 7.42 (2 H, d, J=7 Hz, aryl CH), and 1.36 (9 H, s, t-Bu); uv max (95% EtOH), 235.5 nm (ε 16,000). A solution of 32.73 g (184 mmol) of

the aromatic acid 25 in 250 ml HOAc was hydrogenated at 25° and 40-50 p.s.i. H_2 pressure over the catalyst from 2.068 g of PtO_2 for 48 hr at which time 0.56 mol (1.0 equiv) of H_2 had been consumed. The mixture was filtered and the filtrate was concentrated to leave 34.92 g of crude product as a white solid that contained (nmr analysis) none of the starting aromatic acid 25. A portion of the crude product was recrystallized repeatedly from hexane to separate a sample of cis-4-t-butylcyclohexanoic acid (26) as colorless prisms, mp 117-118° (lit. mp 117-118°,[22] 117.5-118.5°[21]); ir (CCl_4), 2950 (broad, assoc. OH) and 1703 cm^{-1} (carboxyl C=O); nmr (CCl_4), δ 11.8 (1 H, broad, OH), and 0.8-2.8 (19 H, m, aliphatic CH including a t-Bu singlet at 0.84); mass spectrum, m/e (rel intensity), 129 (33), 81 (22), 57 (100), 56 (42), and 41 (28).

In an alternative purification procedure,[22] 1.178 g of a mixture of cis-4-t-butylcyclohexanoic acid (26) and trans-4-t-butylcyclohexanoic acid (31) was dissolved in 30 ml of boiling aqueous 3% NH_3 and then cooled. The less soluble NH_4^+ salt of cis-4-t-butylcyclohexanoic acid (26) that crystallized was collected in several fractions. This salt was acidified with aqueous HCl and the insoluble acid 26 was filtered and recrystallized from hexane to separate 365 mg of the pure acid 26, mp 117-118°.

Preparation of the isomers of 4'-t'-butylcyclohexyl-4-t-butylcyclohexane 27, 28, 29

Following a previously described[9] procedure, a solution of cis-4-t-butylcyclohexanoic acid (26) and its Na salt was prepared by the addition of 4.138 g (22.5 mmol) of cis acid 26 to a solution of NaOMe (from 113 mg or 4.7 mg-atom of Na, 0.21 equiv) in 45 ml of anhydrous MeOH. This solution was placed in an electrolysis cell fitted with two 2 cm x 2 cm Pt plates as electrodes and with a magnetic stirrer and a reflux condenser. The quantity of electricity passed through the cell was monitored with a strip-chart recorder attached to the end of a 1 ohm precision resistor placed in series with the cell current and the potential across the electrodes was monitored with a high-impedance voltmeter. The potential across the electrodes was maintained at approximately 7 volts which gave a cell current in the range 0.56-0.60 amp and maintained the stirred solution at gentle reflux. After a reaction time of 120 min (at which time 4032 coulombs or 1.86 equiv. of electricity had been passed through the cell), the electrolysis was stopped and the resulting yellow solution was partitioned between Et_2O and aqueous NaCl. The aqueous layer was separated, acidified, and extracted with ether to separate 533 mg (13% recovery) of the unchanged cis acid 26. The organic layer was washed successively with aqueous $NaHCO_3$, and with H_2O and then dried, concentrated, and distilled to

separate 16.19 g of low boiling materials (including residual MeOH), bp 35-72°, and left 1.652 g of high boiling residue. Weighed aliquots of these fractions were mixed with known amounts of internal standards (either sec-butylbenzene or n-$C_{15}H_{32}$) for glpc analysis (Carbowax 20M on Chromosorb P, apparatus calibrated with known mixtures). With a column temperature of 105° the retention times were: t-butylcyclohexane (24), 6.0 min; 4-t-butylcyclohexene (22), 9.2 min; sec-butylbenzene, 17.6 min; at 145° the retention times were: 4-t-butylmethoxylhexane (30) (both stereoisomers), 11.0 min; n-$C_{15}H_{32}$, 16.4 min. A collected (glpc) sample of the component believed to be ethers 30 (mixture of stereoisomers) exhibited no ir absorption (CCl_4) attributable to OH or C=O functions with the following nmr peaks (CCl_4): δ 3.50 (s, OCH_3 of one steroisomer), 3.23 (s, OCH_3 of second stereoisomer), and 0.8-2.2 (m, aliphatic CH including a t-Bu singlet at 0.84). These ethers 30 were also observed in the previously described[9] Kolbe reaction with the salts of cis-4-t-butylcyclohexanoic acid (26) and trans-4-t-butylcyclohexanoic acid (31). The calculated (glpc analysis) yields of these lower boiling components were: hydrocarbon 24, 12%; olefin 22, 23%; ethers 30, 5%. A weighed aliquot of the higher boiling products was also mixed with a known amount of n-$C_{18}H_{38}$ as an internal standard for glpc analysis (silicone SE_{30} on Chromosorb P, apparatus calibrated with known mixtures). At 225° the retention times were 11.1 min for n-$C_{18}H_{38}$, 20.2

min for isomeric 4'-t'-butylcyclohexyl-4-t-butylcyclohexanes 27 and 28 (not resolved), and 23.6 min for the other isomer of 4'-t'-butylcyclohexyl-4-t-butylcyclohexane 29; the calculated yields (glpc analysis) were 42% of the mixture of hydrocarbons 27 and 28 and 4% of hydrocarbon 29. In an earlier study,[9] employing a comparable glpc column with silicone SE_{30} on an an inert support, the major products, isomers 27 and 28, were eluted more rapidly and were only partially resolved and the minor product, isomer 29, was eluted more slowly.

By use of a different glpc column (silicone QF_1 on Chromosorb P) all three of the isomeric hydrocarbons could be resolved; the retention times were: n-$C_{18}H_{38}$, 26.6 min; 27, 62.0 min; 28, 65.6 min; and 29, 74.4 min. The composition (glpc) of the mixture was 74% of 27, 13% of 28, and 13% of 29. Samples of each of the three hydrocarbons were collected (glpc) for spectral analyses; each isomer crystallized as colorless prisms as it was collected. The hydrocarbon eluted first, isomer 27 was a solid, mp 125-125.5°. Recrystallization from hexane afforded the hydrocarbon 27 as colorless needles, mp 124-125°; mass spectrum, m/e (rel. intensity), 278 (M^+, < 1), 165 (16), 164 (14), 97 (12), 83 (29), 82 (18), 81 (14), 69 (18), 67 (12), 58 (52), 57 (100), 56 (30), 55 (18), and 41 (25); nmr ($CDCl_3$, 100 mHz), δ 0.7-2.2 (m, aliphatic CH including two t-Bu singlets at 0.83 and 0.84). The hydrocarbon eluted second, isomer 28, was also obtained as a solid, mp 155-156°. Recrystallization from hexane afforded

the hydrocarbon 28 as colorless needles, mp 154-155°; mass spectrum, m/e (rel. intensity), 278 (M^+, <1), 165 (14), 164 (12), 97 (14), 95 (12), 83 (30), 82 (17), 81 (17), 69 (20), 67 (14), 57 (100), 56 (31), 55 (22), 43 (12), and 41 (29); nmr ($CDCl_3$, 100 mHz), δ 0.7-2.2 (m, aliphatic CH including one t-Bu singlet at 0.83). The hydrocarbon eluted last, isomer 29, was a solid mp 190-190.5°. Recrystallization from hexane separated the hydrocarbon 29 as colorless needles, mp 194-195.5°; mass spectrum m/e (rel. intensity), 278 (M^+, <1), 165 (13), 164 (12), 97 (11), 83 (29), 82 (18), 81 (14), 69 (18), 67 (13), 57 (100), 56 (31), 55 (18), and 41 (25); nmr ($CDCl_3$, 100 mHz), δ 0.7-2.2 (m, aliphatic CH including one t-Bu singlet at 0.81).

Preparations of ethereal solutions of diazomethane

Ethereal solutions of diazomethane were prepared by distilling a mixture of diazomethane and diethyl ether from N,N'-dimethyl-N,N'-dinitrosoterephthalamide (33), NaOH, and H_2O[10] or from a mixture of nitrosomethylurethane (35), KOH, H_2O, and $EtOCH_2CH_2OCH_2CH_2OH$.[11] The concentration of CH_2N_2 in these solutions was determined with a Spectronic 20 spectrophotometer by measuring the absorbance at 410 nm and utilizing the value, max (Et_2O), 410 (ε 7.2). The concentration of CH_2N_2 was in the range 0.099-0.139 M.

Preparation of cis-methyl-4-t-butylcyclohexanoate (16)

A solution of 8.104 g (44.0 mmol) of cis-4-t-butylcyclohexanoic acid (26) in 50 ml of methanol was treated with 330 ml of an ethereal solution containing 45.8 mmol of diazomethane and the resulting solution was allowed to stand overnight. After the reaction solution had been concentrated, distillation separated 8.023 g (92%) of the pure (nmr and glpc analysis) cis-methyl-4-t-butylcyclohexanoate (32) as colorless liquid, bp 108° (9mm), that crystallized on standing as colorless prisms, mp 27-27.5° (lit.: bp 54-56° (0.5 mm),[23] bp 102-103° (9 mm),[24] mp 26.1-26.7° [25]); ir (CCl_4), 1740 cm^{-1} (ester C=O); nmr (CCl_4), δ 3.65 (3 H, s, OCH_3) and 0.8-2.9 (19 H, m, aliphatic CH including a t-Bu singlet at 0.82); mass spectrum, m/e (rel. intensity), 141 (50), 140 (76), 87 (26), 81 (63), 67 (25), 57 (100), 56 (34), 55 (26), and 141 (49).

Preparation of trans-4-t-butylcyclohexanoic acid (14)

A solution of 28.47 g (163 mmol) of cis-4-t-butylcyclohexyl chloride (12) in 100 ml of THF was added to 4.25 g (175 mg-atom) of Mg and the resulting mixture was heated to reflux; 1.1 g (5.8 mmol) of $BrCH_2CH_2Br$ was added, and the mixture was refluxed with stirring for 2.5 hr. The resulting

mixture was cooled and the solution of 4-t-butylcyclohexylmagnesium chloride (1) (total volume 120 ml) was siphoned from the excess unchanged Mg. Titration of this solution employing a standard solution of 2-butanol in xylene with 2,2'-bipyridyl as an indicator[26] and titration of a hydrolyzed sample with standard aqueous HCl indicated the concentration of Grignard reagent and total base in the solution were 1.040 M and 1.045 M, respectively. Thus, the total yield of the Grignard reagent was 76%. A 100-ml (104 mmol) sample of the Grignard reagent solution was added slowly to 200 g of crushed solid CO_2 and the mixture was allowed to stand for 12 hr. The resulting mixture was acidified with 75 ml of aqueous 4 M HCl. After the aqueous layer had been saturated with NaCl, the organic layer was separated and the aqueous phase was extracted with Et_2O. The combined organic layers were dried and concentrated, and then the lower boiling components (3.12 g) were removed by distillation at 25-60° (4 mm). The residual solid from this distillation was recrystallized from hexane to separate 12.52 g (65.3%) of trans-4-t-butylcyclohexanoic acid (31) as colorless prisms, mp 176-176.5° (lit.[8] mp 174.5-175°); ir (CCl_4), 2950 (broad, OH), and 1708 cm^{-1} (carboxyl C=O); nmr (CCl_4), δ 12.05 (1 H, s, OH) and 0.8-2.3 (19 H, m, aliphatic CH including a t-Bu singlet at 0.85); mass spectrum, m/e (rel. intensity), 129 (85), 128 (25), 127 (56), 123 (27), 109 (24), 81 (70), 67 (31), 57 (96), 56 (47), 55 (31), 43 (25), 41 (100), and 39 (20).

Preparation of trans-methyl-4-t-butylcyclohexanoate (14)

A solution of 11.85 g (64.3 mmol) of trans-4-t-butylcyclohexanoic acid (31) in 50 ml of methanol was treated with 690 ml of an ethereal solution containing 64.4 mmol of diazomethane and the resulting mixture was allowed to stand overnight. The reaction mixture was concentrated and distilled to separate 11.88 g (93%) of (nmr and glpc analyses) trans-methyl-4-t-butylcyclohexanoate (14) as a colorless liquid, bp 108° (9 mm), n^{25}_D 1.4532 (lit.: bp 65-66° (0.8 mm),[27] 106-107° (10 mm),[24] n^{20}_D 1.4540,[27] 1.4547[24]); ir (CCl_4), 1740 cm^{-1} (ester C=O); nmr (CCl_4), δ 3.60 (3 H, s, OCH_3) and 0.8-2.5 (19 H, m, aliphatic CH including a t-Bu singlet at 0.87); mass spectrum, m/e (rel. intensity), 198 (M^+, 1), 143 (88), 142 (42), 141 (78), 123 (27), 81 (69), 67 (33), 57 (100), 56 (42), 55 (33), 41 (55), and 39 (33).

Separation of cis-methyl-4-t-butylcyclohexanoate (14) and trans-methyl-4-t-butylcyclohexanoate (32)

Mixtures of cis-methyl-4-t-butylcyclohexanoate (14) and trans-methyl-4-t-butylcyclohexanoate (32) could be analyzed by two methods. The trans 14 ester has a higher field nmr signal for the OCH_3 group (δ3.60) and a lower field t-Bu signal (δ0.87) than the corresponding values (δ3.65 and 0.82)

for the cis ester 32. Employing durene as an internal standard for glpc analysis (Carbowax 20M on Chromosorb P, apparatus calibrated with known mixtures), the retention times of the various components were: durene, 10.2 min; cis ester 32, 24.2 min; and trans ester 14, 32.0 min.

Reaction of 4-t-butylcyclohexylmagnesium chloride (1) with CO_2 and D_2O.

A. From cis 4-t-butylcyclohexyl chloride (12).

4-t-Butylcyclohexylmagnesium chloride (1) was prepared by the addition of a solution of cis 4-t-butylcyclohexyl chloride (12) in either Et_2O or THF to excess predried Mg turnings (from triply sublimed Mg). The resulting mixture was heated to reflux, a portion of $BrCH_2CH_2Br$ was added to initiate reaction, and the mixture was refluxed for the time specified. The resulting mixture was cooled and the supernatant liquid was siphoned into a second flask for use. Aliquots of the solution were titrated both with a standard solution of sec-butanol employing 2,2'-bipyridyl as an indicator[26] and with standard aqueous HCl employing phenolphthalein as an indicator. The Grignard reagents obtained using triply sublimed Mg were colorless solutions whereas the reagents obtained with ordinary Mg turnings were brown colored solutions. In Et_2O solution typical preparations gave solutions containing 0.87-1.02 M

Grignard reagent 1 (yields 85-97% based on the starting chloride) and 0.18 M or less residual base. In THF solution, typical preparations gave solutions containing 0.14-1.04 M Grignard reagent 1 (yields 86-94% based on the starting chloride) and 0.06 M or less residual base.

A solution of 4-t-butycyclohexylmagnesium chloride 1 (0.185 M, 89% yield, residual base 0.010 M) was prepared from 887 mg (36.5 mg-atom) of Mg, 1.726 g (9.88 mmol) of cis-4-t-butylcyclohexyl chloride (12), 436 mg (2.3 mmol) of $BrCH_2CH_2Br$, and 50 ml of THF with a reflux period of 3.5 hr. A 23.0-ml aliquot of the Grignard reagent 1 (4.26 mmol of 1) was diluted with 10 ml of THF and cooled to 5°. A stream of anhydrous CO_2 was passed through this solution, with continuous stirring, for 15 min during which time the temperature rose to 14° and then returned to 5°. After the resulting mixture had been stirred at 25° for 10 hr, it was treated with 10 ml of aqueous NH_4Cl, acidified with aqueous 12 M HCl, and extracted with Et_2O. The organic layer was washed with aqueous 3 M NaOH and then concentrated and mixed with a known weight of durene for glpc analysis (Carbowax 20M on Chromosorb P, apparatus calibrated with known mixtures). The low molecular weight compounds in the neutral layer were (glpc analysis) t-butylcyclohexane (24) (ret. time 4.5 min, 13% yield), 4-t-butylcyclohexene (22) (5.6-6.5 min, 3% yield), and durene (27.5 min). The alkaline aqueous extract was acidified and extracted with Et_2O to separate 756 mg (83%) of crude trans-

4-t-butylcyclohexanoic acid (26) and cis-4-t-butylcyclohexanoic acid (31). A solution of these crude acids 26 and 31 in 35 ml of MeOH was esterified with 50 ml of an ethereal solution containing 5.5 mmol of CH_2N_2. The solution was dried, concentrated, and mixed with a known weight of durene for glpc analysis (Carbowax 20M on Chromosorb P, apparatus calibrated with known mixtures). This fraction contained durene (ret. time 8.4 min), cis-methyl-4-t-butylcyclohexanoate (32) (20.4 min, 21% yield), and trans-methyl-4-t-butylcyclohexanoate (14) (27.2 min, 61% yield) corresponding to a mixture of 26% cis ester 32 and 74% of trans ester 14. Collected (glpc) samples of the two esters 32 and 14 were identified with authentic samples by comparison of ir spectra and glpc retention times.

A second 18.0-ml aliquot of the Grignard reagent 1 containing 3.33 mmol of 1 was cooled to 5° and then 1.107 g (6.2 mmol) of D_2O in 10 ml of THF was added, dropwise and with stirring during 10 min. The resulting mixture was stirred overnight and then partitioned between pentane and H_2O. Aliquots of the pentane solution were mixed with known weights of either durene or n-$C_{18}H_{38}$ for glpc analysis. The yields were 88% of t-butylcyclohexane (24), cis-4-t-butyldeuteriocyclohexane (37), and trans-4-t-butyldeuteriocyclohexane (38); 2% of 4-t-butylcyclohexene (22); and 3.3% of the isomers of 4'-t'-butylcyclohexyl-4-t-butylcyclohexanes: 2% of dimer 27; 0.3% of dimer 28; and 1% of dimer 29. A collected (glpc) sample

of olefin 22 was identified with an authentic sample by comparison of ir spectra and glpc retention times. A collected (glpc) sample of hydrocarbons 24, 37, and 38 had the following spectral properties: ir (neat), 2180 (shoulder) and 2160 cm^{-1} (C-D). The resolution obtained in the ^{13}C nmr spectrum (C_6D_6) of the sample was not sufficient to distinguish between deuterated hydrocarbons 37 and 38.[13] A tentative measure of deuterium content of this product was obtained by use of the mass spectral peaks for the fragment ions at m/e 125 to m/e 128 (M^+-15). The composition was 22% d_0 species and 78% d_1 species.

B. From trans-4-t-butylcyclohexyl chloride (23).

The reaction of 1.601 g (9.16 mmol) of trans-4-t-butylcyclohexyl chloride (23) with 603 mg (24.8 mg-atom) of Mg in 50 ml of THF with 654 mg (3.49 mmol) of added $BrCH_2CH_2Br$ (added in three portions) during 5.5 hr yielded a solution of 4-t-butylcyclohexylmagnesium chloride (1) that was 0.14 M (83% yield, 0.007 M residual base). A 30-ml aliquot of this solution was cooled to 6° and then treated with CO_2 for 15 min as previously described. The crude mixture of trans-4-t-butylcyclohexanoic acid (26) and cis-4-t-butylcyclohexanoic acid (31) (709 mg, 76% yield) was esterfied with CH_2N_2 for glpc analysis. The yields were: t-butylcyclohexane (24), 17%; 4-t-butylcyclohexene (22), 2%; cis-methyl-4-t-butylcyclo-

hexanoate (32), 18%; trans-methyl-4-t-butylcyclohexanoate (14), 53%. These values correspond to a mixture of 25% cis ester 32 and 75% trans ester 14.

A 20.0-ml aliquot of the Grignard reagent 1 was treated with a solution of 1.107 g of D_2O in 10 ml of THF as previously described. The yields of products (glpc analysis) were: t-butylcyclohexane (24), cis-4-t-butyldeuteriocyclohexane (37), and trans-4-t-butyldeuteriocyclohexane (38), 92%; 4-t-butylcyclohexene (22), 3%; and the isomers of 4'-t'-butylcyclohexyl-4-t-butylcyclohexane, 4%: 3% of dimer 27, 0.5% of dimer 28, and 0.5% of dimer 29. A collected (glpc) sample of the hydrocarbons 24, 37, and 38 had the following spectral properties: ir (neat) 2180 (shoulder) and 2160 cm^{-1} (C-D). The resolution obtained in the ^{13}C nmr spectrum (C_6D_6) of this sample was insufficient to distinguish between deuterated hydrocarbons 37 and 38.[13] A tentative measure of the mass spectral peaks for the fragment ions at m/e 125 to m/e 128 (M^+-15). The composition was 29% d_0 species, 70% d_1 species, and 1% d_2 species.

Preparation of cis-4-t-butylcyclohexyldimethyl carbinol (50)

To a solution of 2.695 g (13.6 mmol) of cis-methyl-4-t-butylcyclohexanoate (32) in 15 ml of Et_2O was added, dropwise and with stirring during 15 min, 34 ml of an ethereal

solution containing 34.3 mmol of MeLi.[28] The resulting mixture was refluxed for 1 hr and then partitioned between Et_2O and aqueous NH_4Cl. After the organic layer had been dried and concentrated, the residual solid (2.66 g) was recrystallized from pentane to separate 1.482 g (55%) of cis-4-t-butylcyclohexyldimethyl carbinol (50) as colorless needles, mp 48.5-49° (lit.[8] mp 49-50); ir (CCl_4), 3590 and 3400 (broad) cm^{-1} (OH); nmr (CCl_4), δ 0.8-2.2 (m, OH and aliphatic CH including a CH_3 singlet at 1.15 and a t-Bu singlet at 0.85); mass spectrum, m/e (rel. intensity), 183 (7), 109 (21), 59 (100), 57 (34), 56 (30), and 39 (21).

Preparation of trans-4-t-butylcyclohexyldimethyl carbinol (51)

To a solution of 2.417 g (12.2 mmol) of trans-methyl-4-t-butylcyclohexanoate (14) in 15 ml of Et_2O was added, dropwise and with stirring during 15 min, 30.2 ml of an ethereal solution containing 30.5 mmol of MeLi.[28] After the resulting solution had been refluxed for 1.5 hr, it was partitioned between Et_2O and aqueous NH_4Cl. The organic layer was dried and concentrated to leave 2.417 g of residual white solid. Recrystallization from pentane separated 1.514 g (63%) of trans-4-t-butylcyclohexyldimethyl carbinol (51) as colorless needles, mp 101-101.2° (lit.[8] mp 101.5-102°); ir (CCl_4), 3590 and 3450 (broad) cm^{-1} (OH); nmr (CCl_4), δ 0.8-2.2 (m, OH

and aliphatic CH including a CH_3 singlet at 1.09 and a t-Bu singlet at 0.85); mass spectrum, m/e (rel. intensity), 183 (4), 109 (15), 59 (100), 58 (16), 57 (33), 56 (40), 43 (19), and 41 (26).

Preparation of cis-4-t-butylcyclohexyldiphenyl carbinol (52)

To a solution of 2.732 g (13.8 mmol) of cis-methyl-4-t-butylcyclohexanoate (32) in 15 ml of Et_2O was added, dropwise and with stirring during 20 min, 29 ml of an ethereal solution containing 32.8 mmol of PhMgBr.[29] After the solution had been refluxed for 4 hr, it was partitioned between Et_2O and cold aqueous HCl. The organic layer was dried and concentrated to leave 4.687 g of crude solid product. Recrystallization from pentane separated 2.798 g (63%) of cis-4-t-butylcyclohexyldiphenyl carbinol (52) as colorless prisms, mp 84.5-85°; ir (CCl_4), 3590 cm^{-1} (OH); uv (cyclohexane), series of weak maxima (ϵ 334-413) in the region 248-265 with intense end absorption; nmr (CCl_4), δ 7.0-7.6 (10 H, m, aryl CH), 2.65 (1 H, broad, OH), 1.1-1.9 (10 H, m, aliphatic CH), and 0.85 (9 H, s, t-Bu), mass spectrum, m/e (rel. intensity), 304 (15), 303 (54), 184 (39), 183 (45), 180 (50), 167 (47), 105 (74), 91 (55), 77 (35), 72 (32), 57 (100), 55 (28), 43 (57), 42 (46), 41 (45), and 39 (30).

Anal. Calcd for $C_{23}H_{30}O$: C, 85.66; H, 9.38. Found: C, 85.43; H, 9.49.

Preparation of trans-4-t-butylcyclohexyldiphenyl carbinol (53)

To a solution of 2.442 g (12.3 mmol) of trans-methyl-4-t-butylcyclohexanoate (14) in 15 ml of Et_2O was added, dropwise and with stirring during 20 min, 26 ml of an ethereal solution containing 28.9 mmol of PhMgBr.[29] After the resulting solution had been refluxed for 2.25 hr, it was cooled and partitioned between Et_2O and cold dilute aqueous HCl. After the organic solution had been dried and concentrated, the residual white solid was recrystallized from pentane to separate 2.382 g (60%) of trans-4-t-butylcyclohexyldiphenyl carbinol (53) as colorless prisms, mp 98.5-98.8°. Further recrystallization raised the melting point of the carbinol 53 to 99.0-99.2°; ir (CCl_4), 3590 and 3470 cm^{-1} (OH); uv (cyclohexane), series of weak maxima (ϵ 287-428) in the region 247-266 nm with intense end absorption; nmr (CCl_4), δ 7.0-7.6 (10 H, m, aryl CH), 2.24 (1 H, broad, OH), 0.7-2.0 (19 H, m, aliphatic CH including a t-Bu singlet at 0.83); mass spectrum, m/e (rel. intensity), 304 (20), 303 (74), 206 (22), 205 (27), 180 (74), 168 (20), 167 (91), 165 (31), 128 (30), 117 (20), 115 (59), 91 (92), 57 (100), 55 (23), and 41 (50).

Anal. Calcd for $C_{23}H_{30}O$: C, 85.66; H, 9.38. Found: C, 85.68; H, 9.40.

Reaction of 4-t-butylcyclohexylmagnesium chloride (1) with acetone

Reaction of 1.412 g (8.08 mmol) of cis-4-t-butylcyclohexyl chloride (12) and 436 mg (2.33 mmol) of $BrCH_2CH_2Br$ with 921 mg (37.9 mg-atom) of Mg in 40 ml of THF for 3.5 hr yielded a solution of 4-t-butylcyclohexylmagnesium chloride (1) that was 0.160 M (85% yield, 0.005 M residual base). A 38.0-ml aliquot of this solution (containing 6.27 mmol of Grignard reagent 1 was cooled to -3° and then a solution of 1.58 g (27.2 mmol) of acetone (freshly distilled from K_2CO_3) in 10 ml of THF was added, dropwise and with stirring during 15 min, while the temperature was kept at -1° to -3°. The resulting mixture was stirred at -1° to -3° for 20 min and then warmed to 25° and hydrolyzed by the addition of aqueous NH_4Cl. After the mixture had been partitioned between Et_2O and H_2O, the crude liquid product was mixed with known weight of durene for glpc analysis (Carbowax 20M on Chromosorb P, apparatus calibrated with known mixtures). The crude product contained t-butylcyclohexane (24) (ret. time 4.4 min, 79% yield), 4-t-butylcyclohexene (22) (6.7 min, 9% yield), and an unidentified component (18.8 min), and durene (27.6 min). None of the isomers of 4'-t'-butylcyclohexyl-4-t-butylcyclohexane 27-29 were detected by glpc analysis (silicone QF_1 on Chromosorb P). Analysis of the crude product by tlc (silica

gel coating, Et_2O-hexane eluent, 3:7 v/v) indicated the presence of trans-4-t-butylcyclohexyldimethyl carbinol (51) (R_f 0.25) but not cis-4-t-butylcyclohexyldimethyl carbinol (50) (R_f 0.36). The total crude product was chromatographed on silica gel with an EtOAc-hexane eluent to separate 148 mg (10%) of the trans carbinol 51, mp 100.5-101.5°, that was identified with an authentic sample by comparison of ir spectra.

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17. All melting points are corrected and all boiling points are uncorrected. Unless otherwise stated $MgSO_4$ was employed as a drying agent. The ir spectra were determined with a Perkin Elmer, Model 257, infrared recording spectrophotometer fitted with a grating. The uv spectra were determined with a Cary, Model 14, or a Perkin Elmer, Model 202, recording spectrophotometer. The proton nmr spectra were determined at 60mHz with a Varian, Model T-60A, nmr spectrometer and a 100mHz with a JOEL Fourier transform nmr spectrometer, Model PFT-100. The chemical shift values are expressed in values (ppm) relative to a Me_4Si internal standard. The mass spectra were obtained with an Hitachi (Perkin Elmer), Model RMU-7, mass spectrometer. All reactions involving bases or reactive organometallic intermediates were performed under a nitrogen atmosphere.

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